

# **IXPE**

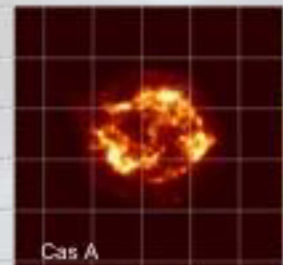
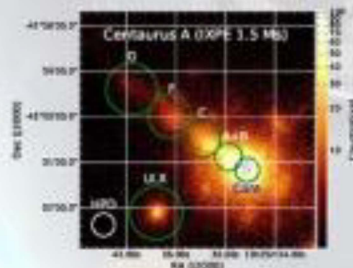
## **Imaging X-ray**

## **Polarimetry Explorer**





- Opens a new window on the universe — imaging (30") X-ray polarimetry
  - The science driver that advances and impacts high-energy astrophysics
  - Increases information space and lifts modeling degeneracies
- Addresses key questions, providing new scientific results and constraints that trace back to the Astrophysics Roadmap and the Decadal Survey
  - What is the spin of a black hole?
  - What are the geometry and magnetic-field strength in magnetars?
  - Was our Galactic Center an Active Galactic Nucleus in the recent past?
  - What is the magnetic field structure in synchrotron X-ray sources?
  - What are the geometries and origins of X-rays from pulsars (isolated and accreting)?
- Provides powerful and unique capabilities
  - Reduces integration time by a factor of 100 over our OSO-8 experiment
  - Simultaneously provides imaging, energy, timing, and polarization data
  - Devoid of instrument systematic effects at less than a fraction of a percent
  - Meaningful polarization measurements for a large number of sources of different classes, as evidenced by our Design Reference Mission








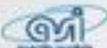








# IXPE Team and Mission



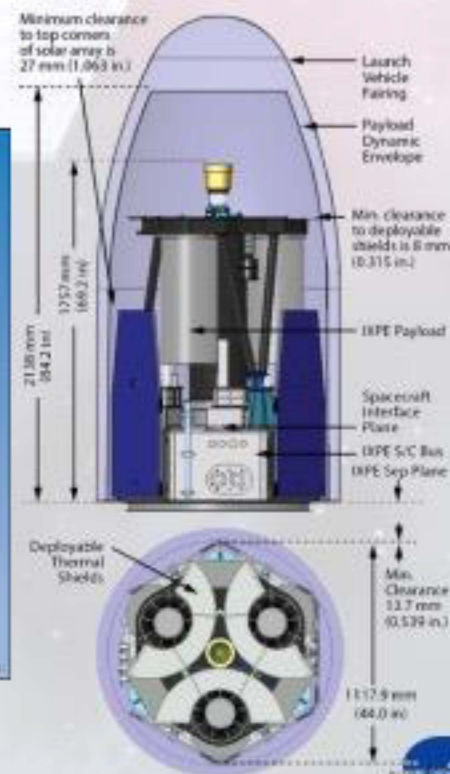
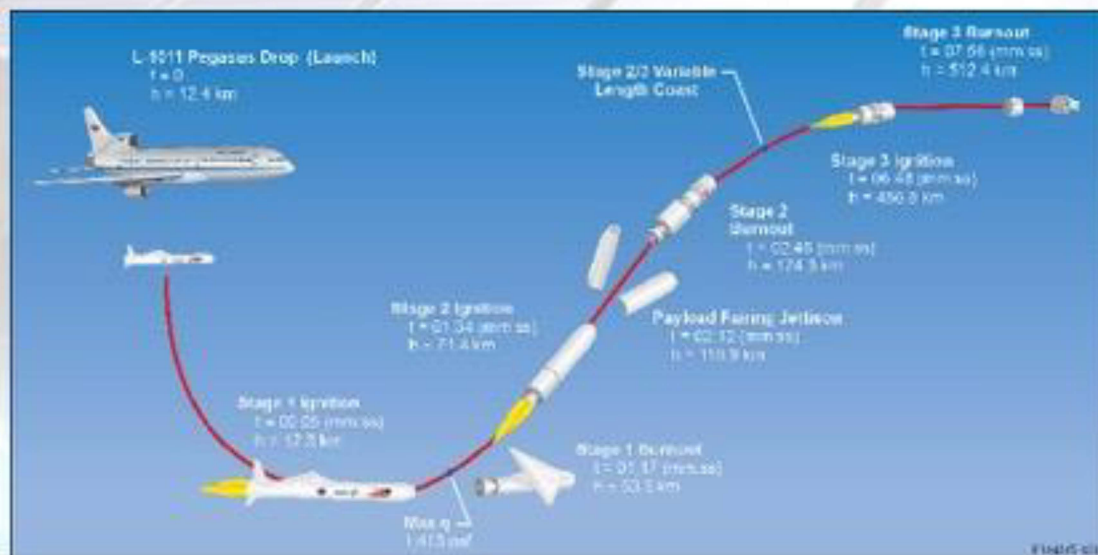
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## Institutional Roles and Responsibilities are Clearly Defined

 <b>Marshall Space Flight Center</b> PI team, project management, SE and S&MA oversight, mirror module fabrication, X-ray calibration, science operations, and data analysis and archiving	  Polarization-sensitive imaging detector systems
 Detector system funding, ground station	 <b>Mission operations</b>
 Spacecraft, payload structure, payload, observatory I&T	  <b>Scientific theory</b>
	 <b>Science Working Group Co-Chair</b>
	 <b>Massachusetts Institute of Technology</b> <b>Student collaboration</b>

## Mission Design and Operations Concept are Straightforward

- NASA Explorer Mission, cost capped at \$175M (FY15)
- Class D Mission managed by MSFC
- XL launch from Kwajalein
- 540-km circular orbit at 0° inclination
- 2 year baseline mission, 1 year SEO
- PI: Martin Weisskopf, MSFC
- Launch ready by end of 2020



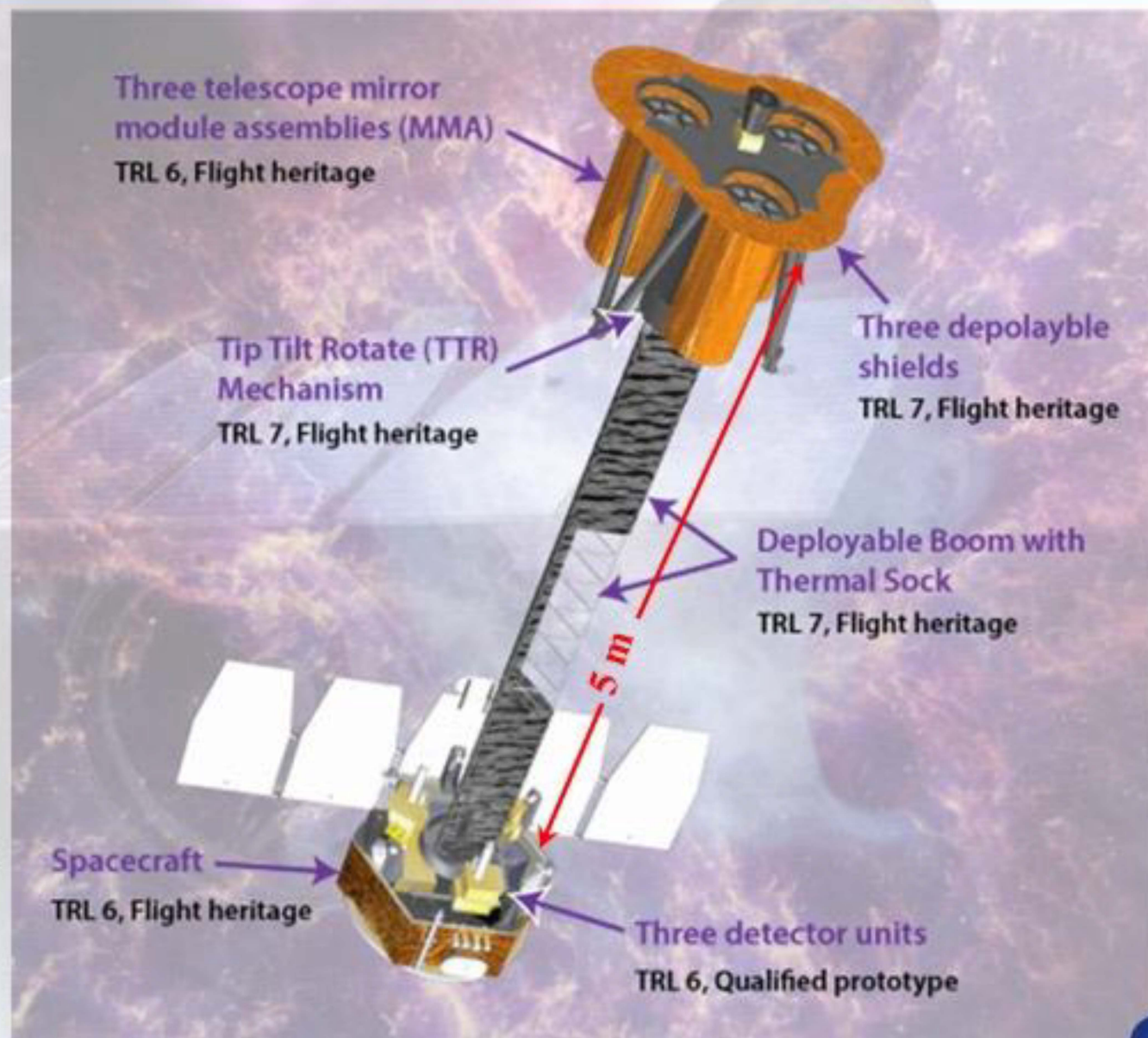




# IXPE INSTRUMENT DESCRIPTION

Measures spatial, spectral, timing, and polarization state of X-rays from 49 known targets

- Set of three mirror module assemblies focus x rays on to three corresponding focal plane detector units.
- Mirror modules provide imaging and background reduction
- Detectors provide position, energy and polarization information, photon by photon, plus time stamp





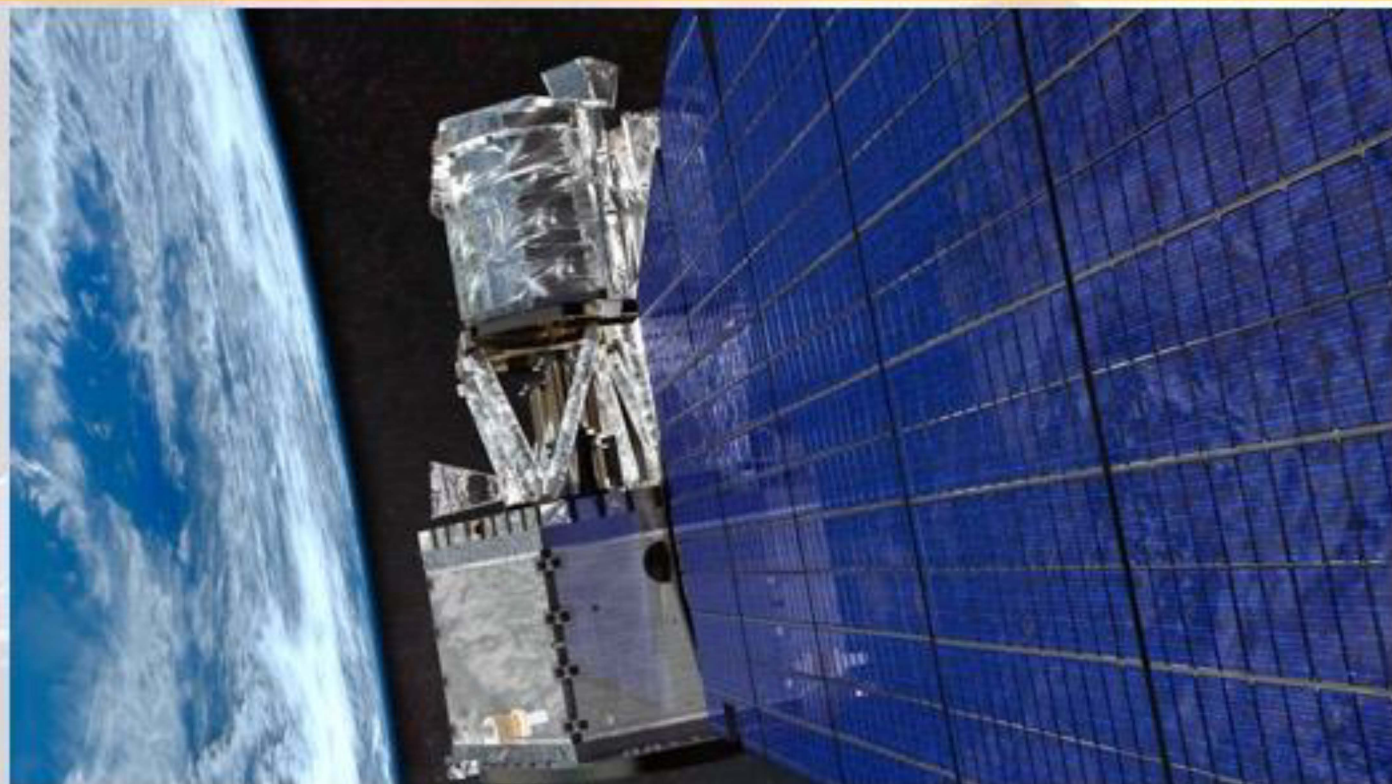
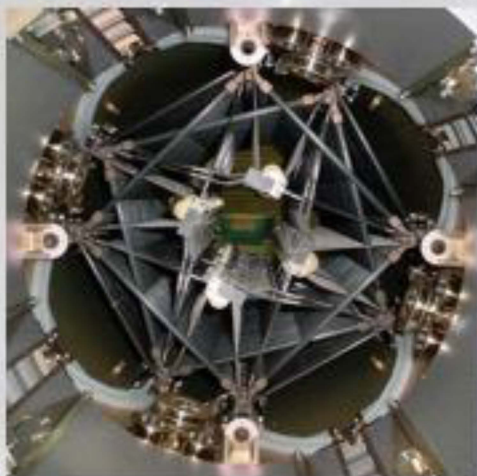


# IXPE Deployment

IXPE



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Property	Value
Mass	4.9 kg
Length	3.64 m
Deployment repeatability	Length: 0.2 mm, Translation: 0.07 mm Twist: 0.27°





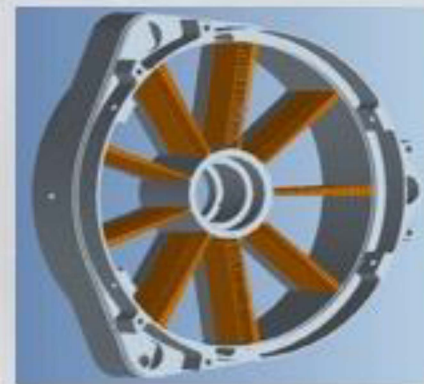
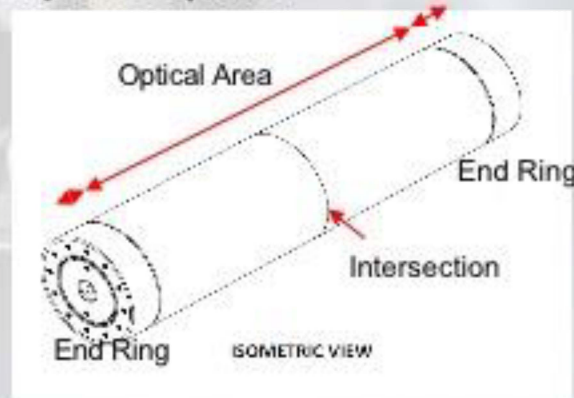
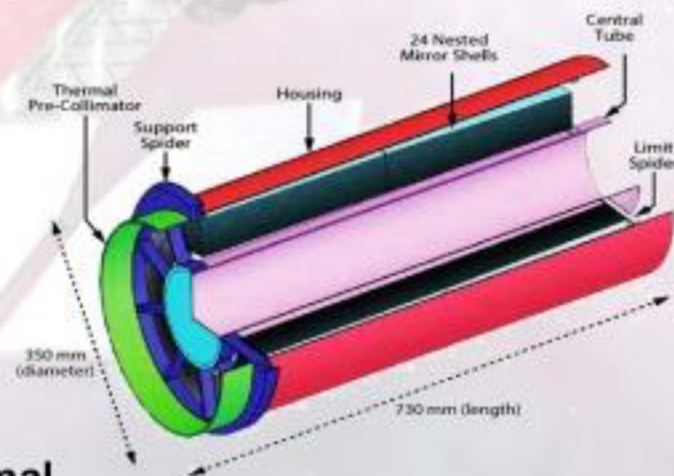
# IXPE Mirror Module Assembly

## MMA Optical Requirements

MMA-7	The combined effective area of all three MMAs with their thermal shields shall be greater than 589 cm <sup>2</sup> at 2.3 keV, and greater than 686 cm <sup>2</sup> at 4.5 keV.
MMA-9	The focal length of each MMA shall be 4000 +/- 1 mm, measured from the node of the optical assembly.
MMA-8	The HPD of each mirror module assembly shall be no greater than 26 arcseconds at 2.3 keV and 4.5 keV on axis.

## MSFC will fabricate:

- 24 mandrels
- 1 engineering unit consisting of 6 shells, 3 mass simulators, 1 external thermal shield, 1 support spider /combs & 1 end capture spider
- 96-102 Nickel – Cobalt (not Ir coated) very thin shells
- 4 flight units (3 + spare) with w/ 24 nested shells, external thermal shield, spider /combs & end capture spider







# Replicated Optics Manufacturing at MSFC

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1. CNC machine, mandrel formation from Al Bar



2. Chemical clean and activation & Electroless Nickel (EN) plating



Currently contracted out

3. Precision turn to sub-micron figure accuracy



4. Polish and superpolish to 3-4 Å finish



5. Metrology – repeat Step 4 until surface finish met



6. Ultrasonic clean & passivation to remove surface contaminants



7. Electroform nickel shell onto mandrel



8. Separate optic from mandrel – reuse mandrel for next shell



8. Align shells into module



9. Test module





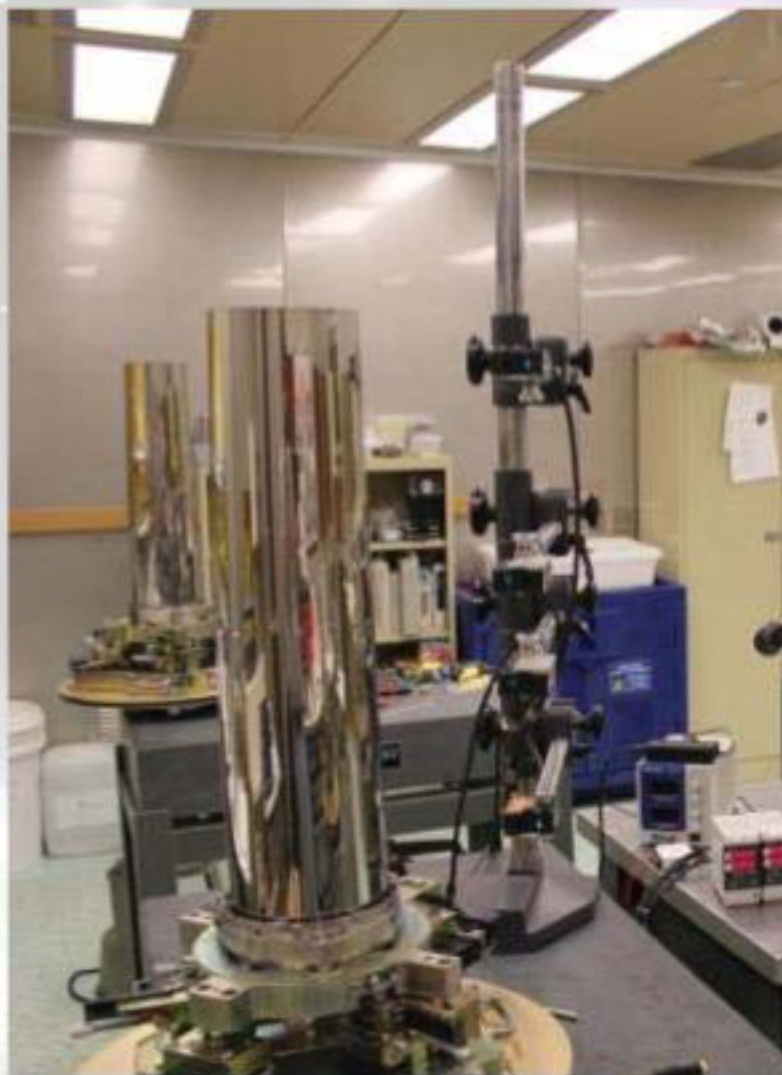


# IXPE Alignment System

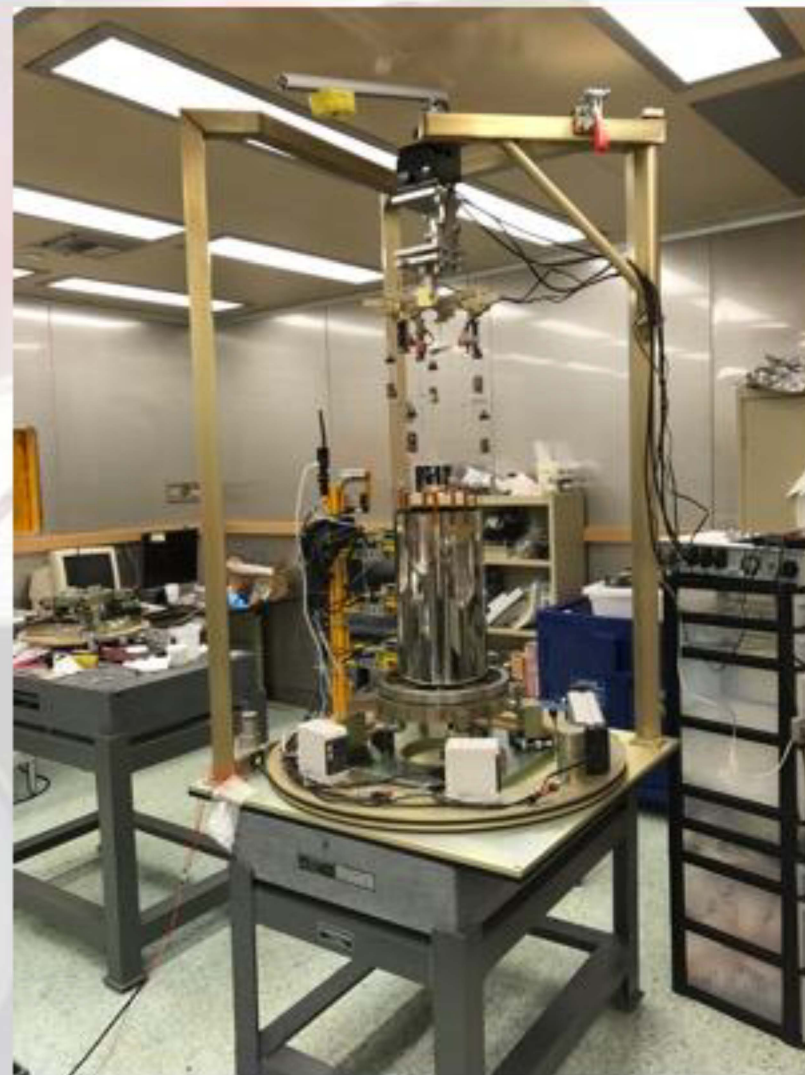
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ART-XC shells supported from 3 points during the alignment and bonding process



IXPE shells are  $\frac{1}{2}$  the thickness of ART and will be gravity off-loading during the alignment and bonding process





# MSFC X-ray Optics Heritage

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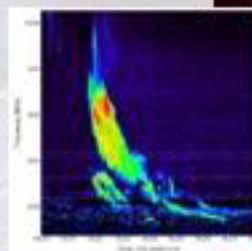


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Parameter	FOXSI -1 (-2 & 3)	ART-XC	IXPE
Number of mirror modules	7	7 (plus 1 spare)	3 (plus 1 spare)
Number of shells per mirror module	7 (10 for selected modules)	28	24
Focal length	2000 mm	2700 mm	4000 mm
Total shell length	600 mm	580 mm	600 mm
Range of shell diameters	38 – 52 mm	50 – 150 mm	162 – 272 mm
Range of shell thicknesses	0.25 mm	0.5 mm	0.18 – 0.26 mm
Shell material	Electroformed nickel–cobalt alloy Coating: > 30 nm of iridium (> 90% bulk density)	Electroformed nickel–cobalt alloy Coating: > 10 nm of iridium (> 90% bulk density)	Electroformed nickel–cobalt alloy
Effective area per mirror module	150 cm <sup>2</sup> (200) at 8 keV, 14 cm <sup>2</sup> (40) at 15 keV	≥ 65 cm <sup>2</sup> at 8 keV (on axis)	210 cm <sup>2</sup> (at 2.3 keV); > 230 cm <sup>2</sup> (at 3–6 keV)
Angular resolution (HPD)	10 arcsec	25 arcsec HPD on axis (measured)	≤ 25 arcsec HPD on axis



- FOXSI Free Flyer addresses the fundamental processes of impulsive energy release and particle acceleration in the solar corona.
- FOXSI will achieve this through focused hard X-ray imaging with **100 times better sensitivity and dynamic range** than previous instruments (e.g. RHESSI).
- FOXSI will observe emission from energetic electrons:
  - directly in the acceleration site in the corona such as near flare reconnection sites or CME shocks,
  - as they travel through the corona,
  - where they are stopped in the chromosphere, and
  - as they escape into interplanetary space.



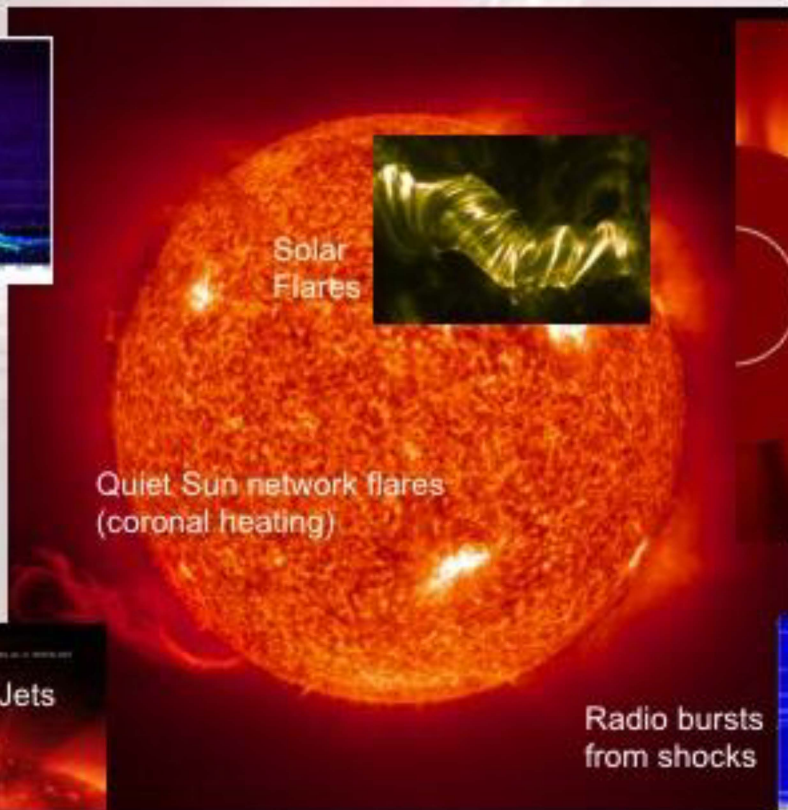
Type III radio bursts



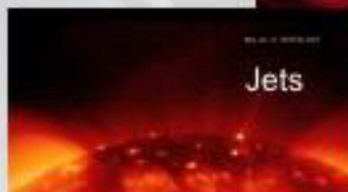
Solar Flares



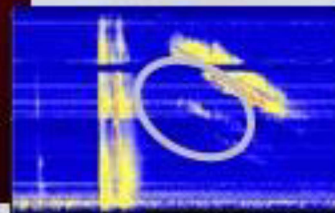
Coronal Mass Ejections



Quiet Sun network flares (coronal heating)



Jets



Radio bursts from shocks





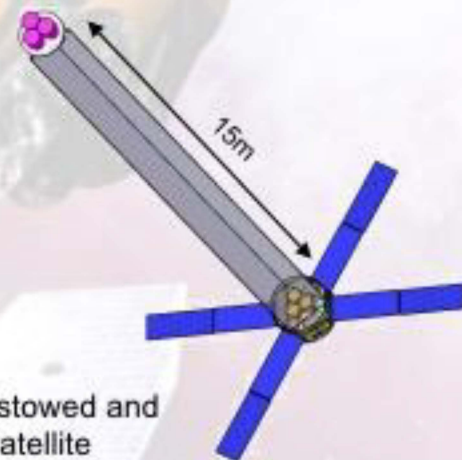
# FOXSI Free Flyer Hardware

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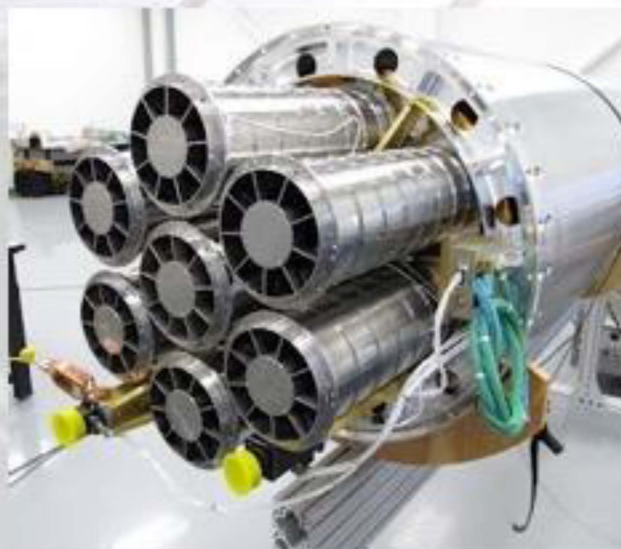


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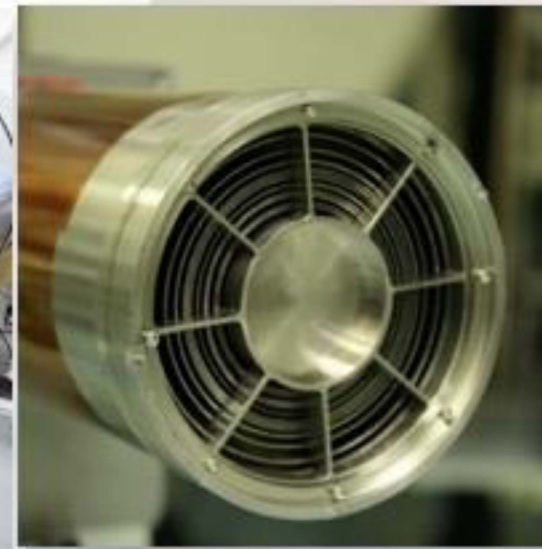
- If selected MSFC will provide 2 flight modules + 1 spare module, fully calibrated, each with 15 or 20 shells
- X-ray optics is a Tier 1 for Scientific Research at MSFC
- FOXSI science requires high-resolution hard x-ray optics, niche area for MSFC – no domestic competitors
- Sub-Orbital Development (significant)
  - FOXSI rocket flights (Nov. 2012, Dec. 2014), FOXSI-3 on schedule
  - HEROES balloon flight (Sept. 2013)
- Orbital Development
  - ART-XC fabricated and delivered by MSFC
  - IXPE SMEX Development



Schematic representations of stowed and deployed FOXSI SMEX satellite



Seven FOXSI Mirror Modules mounted on rocket



FOXSI (rocket) Mirror Module fabricated at MSFC